

## The Aging of Sidestream Tobacco Smoke Components in Ambient Environments

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### Summary

A large number of sidestream smoke components have been measured over a 50-min time period in a well-defined experimental room. The results show a variable rate of decay following smoking which would suggest that extrapolation from a single measured "marker" to other potential smoke components should be performed with caution.

### Introduction

Environmental tobacco smoke is a dynamic aerosol and its characteristics, both physical and chemical, depend on a number of factors; these include the elapsed time since its formation, whether the smoke plume is allowed to fully form before dispersion and the more general dilution within the ambient environment [1]. In terms of a single point sampling site the resultant measurement value will therefore not only depend upon the characteristics of the environment and the number and manner of cigarettes being smoked but also upon both temporal and spatial factors of the sampling position relative to the smoking.

This dynamic nature of the aerosol results not only in a loss of volatile components, including nicotine, from the particles to the vapour phase, but also in a complex and variable behaviour of the individual chemical components which manifests in their exhibiting different decay characteristics. This is of importance in the interpretation of ambient air studies which are generally limited to the measurement of one or two environmental tobacco smoke markers.

The objective of this paper is to demonstrate this variability in decay patterns for a series of chemical measurements over a 50-min period following smoke generation in a well defined experimental room.

### Materials and Methods

Smoke was generated using a modified smoking head from a Battelle rotary smoking machine [2] in a specially constructed room with a volume of about 48,000 litres. The internal walls, ceiling and floor were coated with a sealant paint and there was a single door with no windows, other than a sealed observation port; all other access, including that for electricity supply and air sample collection, was through sealed ducting. During the current studies there was no active ventilation in the room and furniture was kept to a minimum. Temperature and humidity were monitored continuously.

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At the start of each experiment 16 cigarettes, with a standard mainstream delivery of 17 mg tar (PMWNF), were smoked on the rotary smoker to the reference conditions of one 35 ml puff of 2 s duration every minute. The mainstream smoke was ducted away and the sidestream smoke, after formation of the plume, mixed into the room by a series of fans. In order to maintain a constant carbon monoxide level in the room throughout a 50-min-study period, as a standard condition, single cigarettes were smoked subsequent to the initial 16 cigarettes being extinguished. The time at which the initial cigarettes were extinguished was also taken as time zero for the commencement of chemical measurement.

Ambient chemistry in the room was measured using the following techniques which have also been employed, for comparative purposes, in a benchtop collection device [3] for the measurement of freshly generated sidestream smoke:

Carbon monoxide was measured continuously using a non-dispersive infra-red analyser (Analytical Development Co., Model RFA/1).

Nicotine, which is distributed between the particulate and vapour phases, was measured as total nicotine by collection into a Tenax trap over 5-min-sampling periods, with subsequent thermal desorption and gas chromatographic analysis (Perkin-Elmer, ATD50).

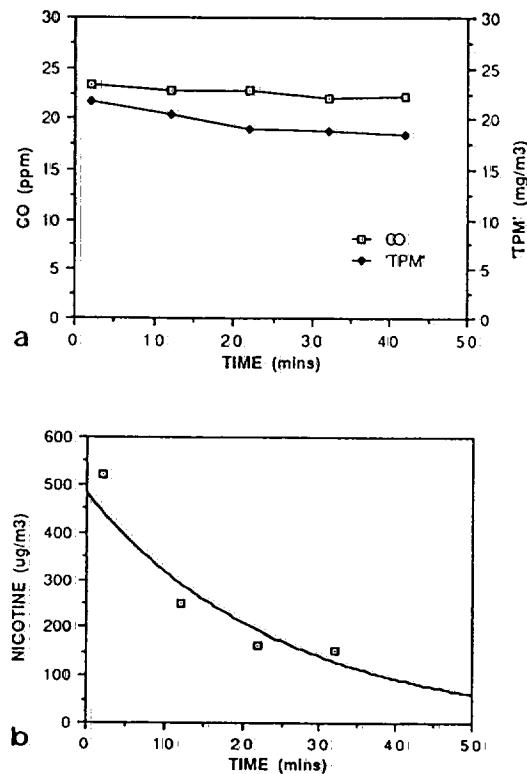


Fig. 1: a Changes in ambient concentrations of carbon monoxide and "Miniram" particulates. b Changes in ambient concentration of nicotine.

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Particulates were measured using the MINIRAM (Miniature Real-time Aerosol Monitor, GCA Corporation, Model PDM-3), a light scattering device which samples over 10-s-time periods. This instrument gives a quantitatively high result because of its sensitivity to particle size distribution and its dependence upon a relevant calibration [4].

Ammonia was measured continuously using a selective ion electrode.

A "whole smoke" gas chromatographic profile was obtained by actively drawing the ambient atmosphere through standard Perkin Elmer ATD50 tubes packed with Tenax TA, 60-80 mesh for a 15-min-period at a flow rate of 300 ml/min. The Tenax was then thermally desorbed in two stages onto a 50 m mixed Ucon phase capillary column. Values for 33 distinct peaks were calculated as the peak area relative to that of the Internal Standard (Dimethyl Furan), these included Acetone, Acrolein, Acetonitrile, Pyridine and 3-vinyl pyridine.

A "phenolic profile" was obtained by drawing the atmosphere through a small Cambridge filter pad for 10 min at a flow rate of 20 l/min. The pad was then silylated using BSTFA and Digol was added as an Internal Standard. This was then heated for 1 h at 80°C and run on a 25 m SE54 capillary column. Values for 26 peaks, including Catechol, Glycerol, and Hydroquinone were calculated with reference to the Internal Standard.

### Results

Figures 1a and 1b show the results for nicotine, carbon monoxide and Miniram particulates. The carbon monoxide levels remain constant at the relatively high level of 22 ppm throughout the 50-min-study period, this being consequent upon the defined

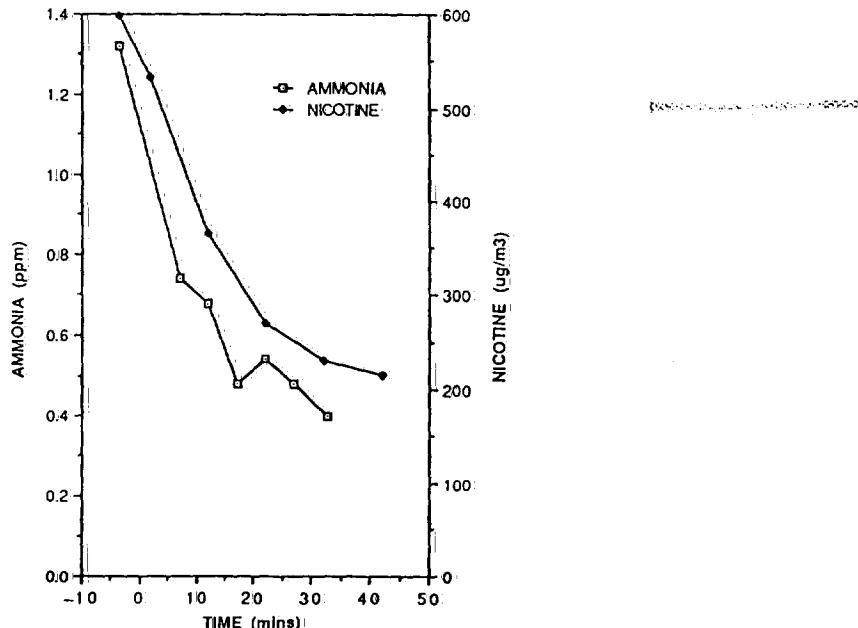


Fig. 2. Changes in ambient concentration of nicotine and ammonia

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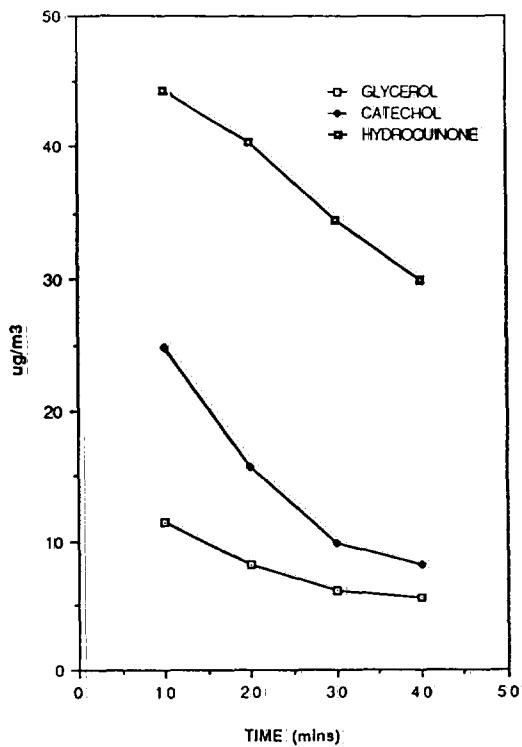


Fig. 3. Changes in ambient concentration of Catechol, Glycerol and Hydroquinone

smoking regimen. The particulate levels can be seen to fall by about 15% and this is most likely accounted for by the loss of volatile materials to the ambient atmosphere. In contrast to this relatively small decline in particulate levels however is the rapid fall in airborne nicotine levels which decay to less than 20% of their initial value.

Figure 2 shows that the levels of ammonia exhibit a similar rapid decay to that seen for nicotine.

Examples from the analysis of the "phenolic profile" are given in Fig. 3 which illustrates the decay of Catechol together with Glycerol and Hydroquinone. These results draw attention to the fact that whilst the majority of components appear to show an exponential decay pattern this is not invariable and as an example Hydroquinone appears to decay over this time period in a linear fashion.

Because of the longer periods over which the "whole smoke" profile samples are obtained it is not possible to display the changes graphically. Comparing the time periods 0-15 min with 30-45 min gives some idea of the variability in rates of decay. These are illustrated in Table 1 where the percentage change of individual peak areas between the two periods can be seen to range from 0% to 40%.

Of the 50 plus components of sidestream smoke examined in these studies in no case was any component found to increase over the 50-min-time period.

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Table 1. Levels of major components in the "whole smoke" profile of an ambient air sample and their % change over a 45-min-time period

Peak No.	Identification	15-30-min-value	45-60-min-value	% change
1		1.51	1.64	-5
2		0.62	0.61	-13
3		4.40	3.94	-22
4		0.65	0.74	0
5		0.52	0.46	-22
6		0.36	0.30	-27
7	Acetone	0.77	0.87	0
8	Acrolein	0.34	0.38	-3
9		1.28	1.22	-16
10	Pyridine	1.05	1.10	-8
11	Acetonitrile	0.67	0.68	-11
12		0.68	0.58	-25
13	Benzene	2.66	2.36	-22
14		0.52	0.53	-10
15	<i>Int. Standard</i>	1.00 (33.5)	1.00 (29.4)	
16	Toluene	4.51	5.20	0
17		0.79		
18		2.31	1.93	-27
19		2.29	1.73	-34
20	3-Vinyl pyridine	0.70	0.76	-5
21	Phenol	1.99	2.28	0
22		2.25	1.75	-32
23		0.89	0.75	-26
24		1.20	1.00	-27
25		1.31	1.23	-7
26		3.53	3.00	-15
27		1.92	1.90	-13
28		1.45	1.40	-3
29		1.83	1.56	-17
30		2.01	1.68	-21
31		1.64	1.25	-33
32		1.02	0.74	-36
33		0.65	0.44	-40

Values presented were calculated by the (peak area of component)/(peak area of Internal Standard). Values in brackets were the actual peak areas. The % change between the results allows for the differences in value for the Internal Standard

### Discussion

The results presented in this paper clearly demonstrate the variability in the decay pattern for individual components of environmental tobacco smoke. Although the measurements were made in an experimental situation at a relatively high ambient smoke level, this variability would certainly be encountered in the real-life situation.

It is thus clear that to make extrapolations from the measurement of a single marker to the behavior of other smoke components involves an assumption which is likely to be

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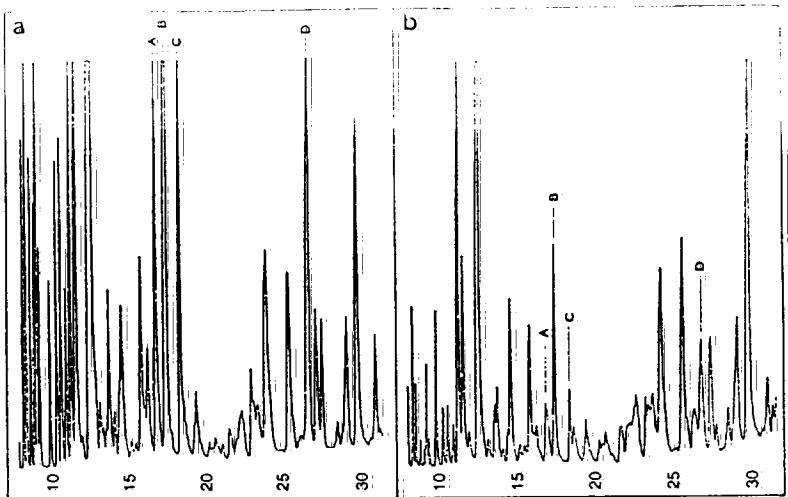


Fig. 4a, b. "Whole smoke" chromatographic profiles of (a) freshly generated sidestream smoke in a benchtop apparatus and (b) environmental tobacco smoke following the dispersion of sidestream smoke from 16 cigarettes

invalid. One further point can be noted from a comparison between fresh sidestream smoke measured in a benchtop apparatus and sidestream generated in the experimental room. This is illustrated in Fig. 4 which presents the whole smoke profiles obtained in a Keith apparatus with that taken in the experimental room immediately following the smoking of the 16 cigarettes. The four components labelled A, B, C and D, which have been provisionally identified as Furan, Acetone, Acrolein and Acetonitrile, are among those which can be seen to have greatly reduced levels in the room relative to those in the benchtop collection device. Although these components appear in fresh smoke their apparent decay is so rapid that they may not be seen to any significant extent in room air.

### Conclusions

- 1) Environmental tobacco smoke is a dynamic aerosol which exhibits both temporal and spatial variation.
- 2) Each of the components of smoke measured has its own decay rate and pattern. Relative to carbon monoxide and particulates, nicotine and ammonia have rapid decay rates. Other components, which probably include Acrolein, decay at an even faster rate and high airborne levels are probably never achieved.
- 3) Extrapolations from benchtop sidestream measurement to room air based on simple dilution calculations is unlikely to provide valid information.
- 4) Extrapolations from a measured "marker" in ambient air studies to other potential smoke components should be performed with caution.

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